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LSD 36 Well Deck Fire Protection

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Large scale fire tests were conducted to evaluate proposed systems for protection of the well deck area on LSD 36 Class ships. The fire threat involves the crash of a helicopter on the flight deck spilling burning JP-5 fuel onto the landing craft and vehicles stored in the well deck below. Based on these tests, the optimum fire protection system would involve an Aqueous Film Forming Foam spray system in which the foam would be dispensed from alternating fan and straight stream nozzles located in a piping system mounted to the wing walls. The direction of the nozzles would be arranged such that one fan nozzle would be pointed downward at an angle of 15° from the vertical and a straight stream nozzle at 60° from the vertical to provide complete coverage. This arrangement was shown to suppress even the worst conflagration in the well deck within 60 seconds so that manual fire fighting, if required, could be conducted from the catwalk.

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LSD 36 WELL DECK FIRE PROTECTION

INTRODUCTION

The Naval Research Laboratory was tasked by the Naval Sea Systems Command to evaluate proposed concepts for a fire protection system for the well deck area on the LSD 36 Class ships.

The well deck area, which is located in the aft part of the ship (see Fig. 1), is used for storage and staging of landing craft (LCMs), vehicles and Class A materials. The area is over 130 m (400 ft) long and approximately 16 m (50 ft) wide. The worst case fire threat for the well deck area involves the crash of a helicopter on the flight deck above spilling up to 2200 gallons of JP-5 fuel onto the LCMs below, which are loaded with personnel, vehicles and supplies.

Normally, an Aqueous Film Forming Foam (AFFF) sprinkler system would be recommended for this application, but the construction of the well deck precludes the use of sprinklers. Approximately one-third of the well deck has no permanent overhead so conventional overhead piping and sprinkler heads cannot be installed. Therefore, the piping for the proposed fire protection system must be mounted on wingwalls. With this limitation, two concepts were proposed: one involved the use of long reach nozzles mounted directly to the piping on the wingwall and the other used oscillating nozzles mounted in such a way as to provide complete foam coverage for this well deck area.

A further limitation on the proposed system was the availability of AFFF in this part of the ship. The existing shipboard AFFF system has a maximum capacity of 11 m^3 (2900 gpm) which could be used for this system. Given the total area of the well deck and likely system zoning arrangements, this converts to a maximum allowable application rate of AFFF of no more than 6.5 $l/min/m^2$ (0.16 gpm/ft^2) for the well deck system.

OBJECTIVE

The objective of this program was to develop a fixed AFFF fire extinguishing system for the LSD 36 class ships which will provide maximum protection for the well deck area, and limit the damage to the landing craft in the well deck (and their contents), within the allowable AFFF application rate.

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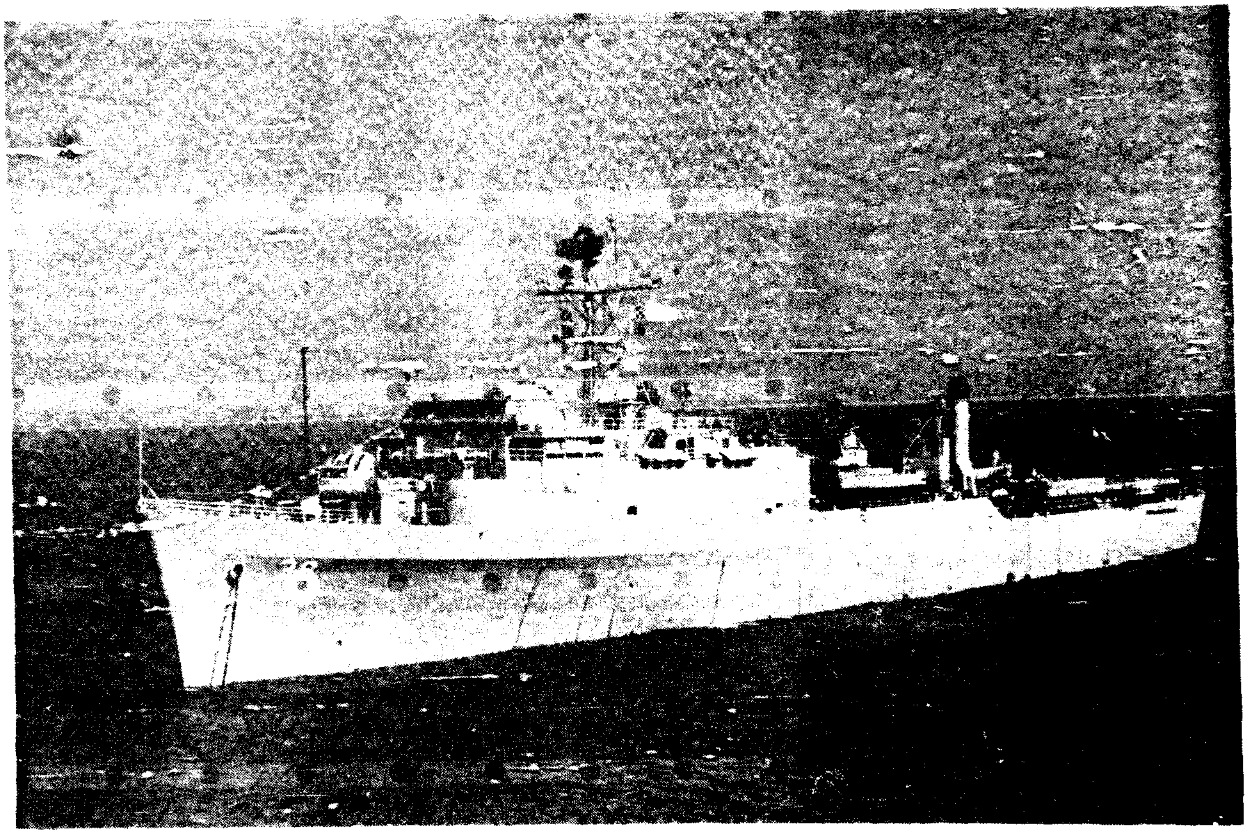

Fig. 1 - USS ANCHORAGE LSD 36

APPROACH

To test the proposed concepts, a mock-up of the well deck area was constructed on the minideck at the Naval Weapons Center, China Lake, CA. The minideck, which is shown in Fig. 2, consists of 37.8 m x 21.7 m (124 ft x 71 ft) concrete pad to simulate an aircraft carrier flight deck. A C-97 aircraft is located on the east end of the minideck to provide typical flight deck wind conditions. The mock-up, which was placed on the west end of the minideck, was constructed of sea containers, 2.4 m (8 ft) wide x 2.4 m (8 ft) high and 6.1 and 12.2 m (20 and 40 ft) long. The sea containers were stacked and arranged to simulate the well deck area of LSD 36 (Fig. 3). In addition, operational constraints required that piping be located as far up on the bulkhead as possible, approximately 6.1 m (20 ft) above the deck. Therefore, the initial system recommended, and the primary system utilized in this fire test program, was essentially a sidewall sprinkler system. Although conventional sidewall heads were not used, long reach nozzles, similar to those designated as deck edge nozzles on carrier flight decks, were utilized in the configuration proven most effective by these fire tests.

The basic system design envisioned in the SHIPALT planning, and the one tested in this T&E program, involved use of supply piping below the catwalks (and open deck areas) located along the sides of the well deck area. This would place the piping approximately 6.1 m (20 ft) above the deck. As stated, the design was based on the use of nozzles attached directly to the supply piping rather than nozzles (or sprinkler heads) attached to piping over the well deck area. The piping arrangement installed in the test mock-up allowed a nozzle spacing of 2.3 m (7.5 ft) for the first test series and a spacing of either 4.6 or 6.1 m (15 or 20 ft) for the second series. The piping layout is shown in Fig. 3 (for the first series only) and in Fig. 4 (for the second series).

Spray nozzles tested were the Bete NF30030 and NF30080X for the first test series and the Bete NF40000 and NF40030 for the second series. The spray nozzles were tested at different spacings (and thus flow rates) and angles, since identification of a fixed nozzle configuration would present a best case for ease of installation and maintenance. Two system heights were evaluated; 3 and 6.1 m (10 and 20 ft) above the deck, to represent a fully flooded and empty well deck, respectively. The nozzle configuration tested in the first series featured eight nozzles spaced 2.3 m (7.5 ft) apart along each supply pipe. This limited the flow rate per nozzle to 114 l/min (30 gpm) (in order to limit the average application rate to 6.1 $l/min/m^2$) (0.16 gpm/ft^2)). The nozzles, Bete models NF30030 and NF30080X, were alternately placed pointing "downward" (0, 30 or 60 degrees from vertical) and "out" (0, 30, or 45 degrees from horizontal), respectively.

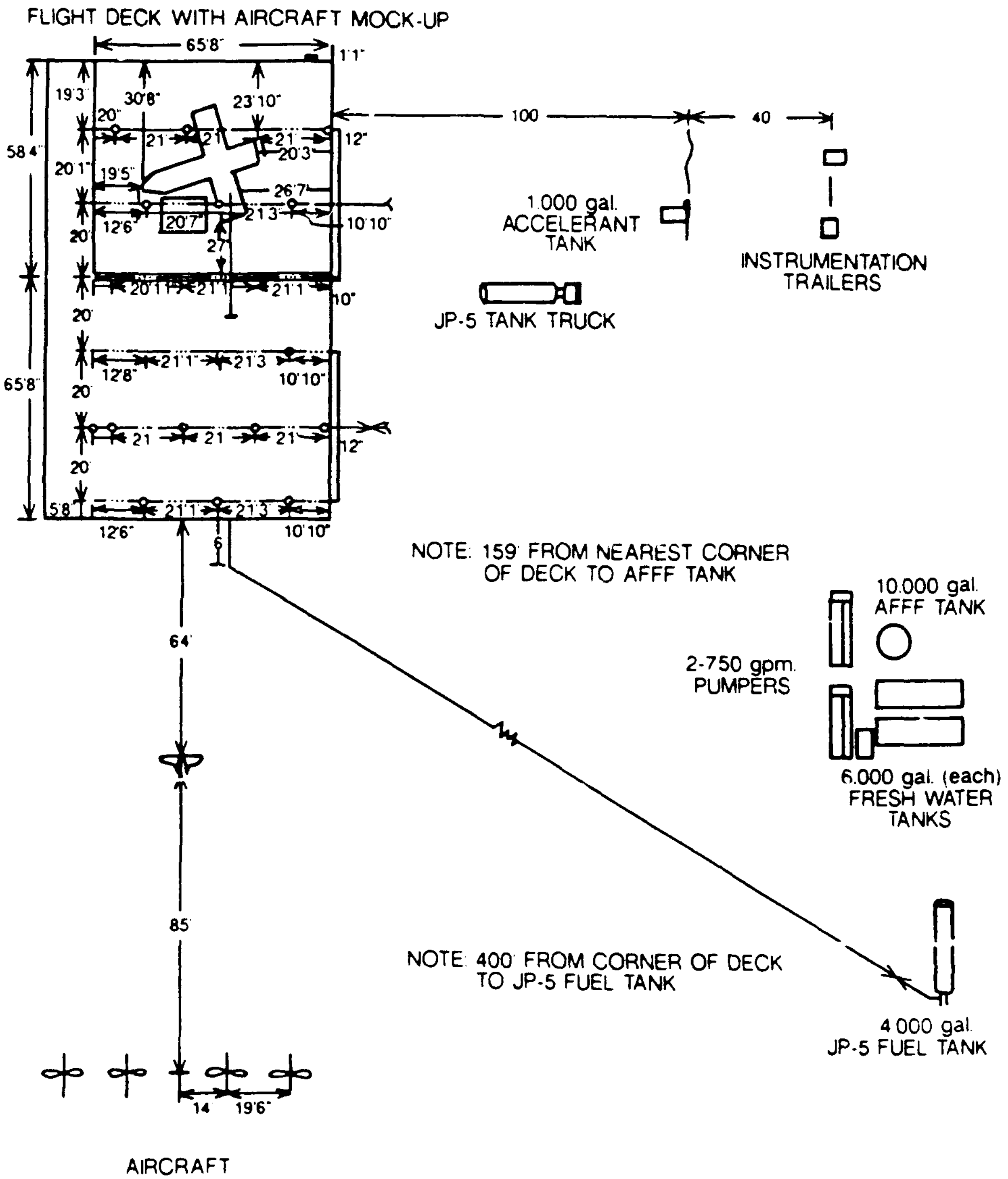

Fig. 2 - Diagram of minideck

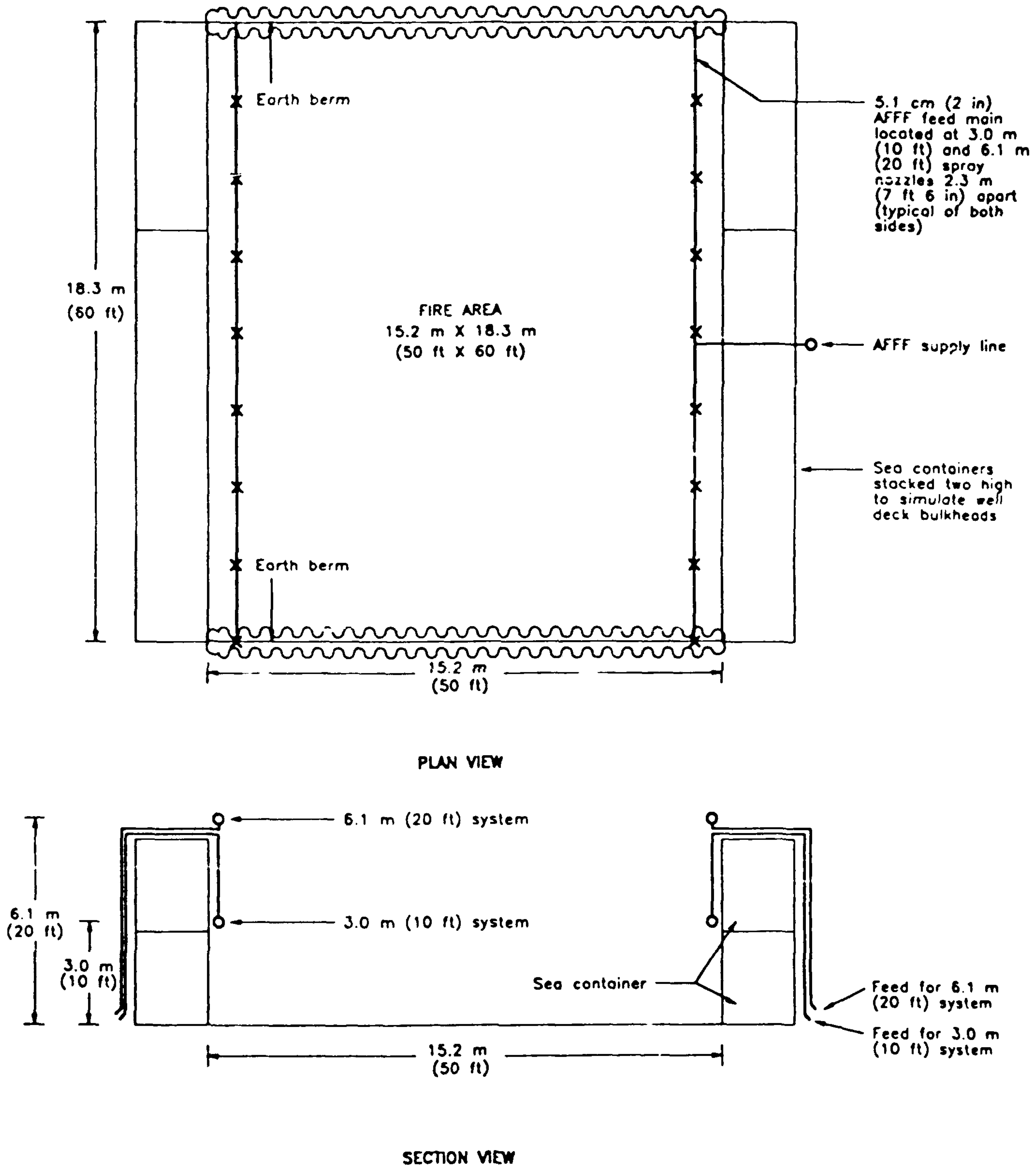

Fig. 3 - Initial test layout (9/86 tests) - Phase I

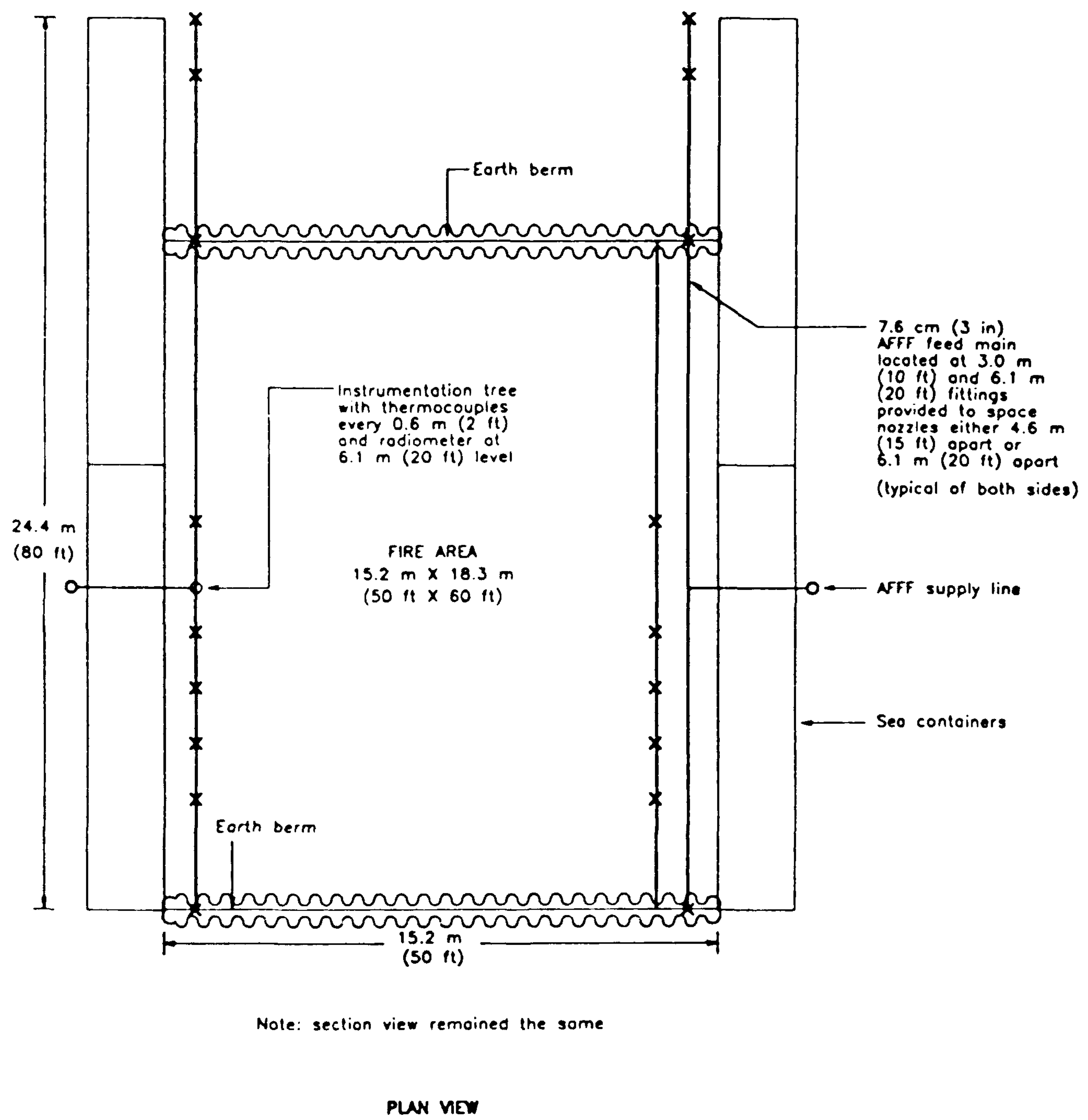

Fig. 4 - Modified test layout (3/87 tests) - Phase I

The nozzle angle is critical for two reasons. First, the angle determines how much additional horizontal spread rate is added to the foam spread rate by the velocity of the stream. That is, the foam will spread out from the point of discharge as it flows across the liquid surface, but this rate of spread can be increased (in one direction) by the horizontal component of the force (velocity) of the discharge stream. Secondly, when landing craft are located in the well deck, the nozzle angle will determine whether the discharge stream, either in whole or in part, will strike the fuel surface or the interior of the landing craft. Unfortunately, the potential combination of number, types, and positions of the landing craft are almost limitless and therefore no nozzle angle (or angles) will be ideal in all circumstances.

Therefore this test series was necessary to determine the optimum values for flow rate, spacing, and angle for the varicus nozzle types being considered.

In addition, vari-nozzles, the same type as are currently used for shipboard fire fighting, and oscillating monitors were also evaluated. The vari-nozzles were installed on the piping as follows:

1. 3.8 cm (1½ in.) vari-nozzle, 6.1 m (20 ft) above the deck, at 6.1 m (20 ft) spacing and using a 30° fog pattern;

2. 6.4 cm (2½ in.) vari-nozzle, 3.1 or 6.1 m (10 or 20 ft) above the deck, at 18.3 m (60 ft) spacing and using a 60° fog pattern.

The oscillating monitors were mounted on top of the wing walls either at opposite ends or at the same end of the well deck.

The tests were conducted in two phases. In the first phase, nozzle type and orientation were evaluated and, in the second phase, simulated landing craft were placed in the well deck to provide a more stringent test of the system selected in Phase I.

Fire Scenario

The fire scenario for the first test series was a simple (open) pool fire throughout the 279 m^2 (3,000 ft^2) area bounded by the sea containers and two earth berms. The test plan called for the use of approximately 3036 l (800 gal) of JP-5 fuel "sweetened" with 76 l (20 gal) of motor gasoline. This was intended to simulate a helicopter crash on the overhead helicopter deck with a loss of the fuel inventory into the well deck. The prevailing wind generally came straight down the centerline of the mock-up deck. The test plan originally precluded testing when the wind velocity exceeded 5 knots, however tests were conducted with a greater ambient wind speed due to time constraints on the completion of the tests. Thermocouple trees and radiometers were placed in the catwalk as shown in Fig. 3 to indicate the time when the temperature and heat flux were sufficiently low for fire teams to enter the catwalk and commence manual fire fighting, if necessary.

Test Plan

The test layout described above specified a nozzle spacing of 2.3 m (7.5 ft). Given the maximum density of 6.1 l/min/m^2 (0.16 gpm/ft^2) specified in the SHIPALT, this translates to a flow of 114 l/min (30 gpm) per nozzle. With the deck edge nozzles being considered, the Bete NF30030 and NF30080X, this translated to a nozzle pressure of 280 kPa (40 psi). Therefore, preliminary tests were conducted using water only to determine the initial nozzle angles, and the pump settings (RPM and pump outlet pressure) necessary to provide the required flow.

The test plan was based on alternating the angle of the nozzles. Half the nozzles were pointed "down", i.e., discharging closer to the bulkhead, while the other half pointed "out", i.e., discharging more towards the center of the well deck. In addition to alternating along one bulkhead, the nozzles opposing each other were of the opposite configuration, i.e., a "downward" nozzle was opposed by an "outward" nozzle.

Based on water only tests, an initial set of nozzle angles was to be selected. If this test proved marginal or unsuccessful, the application rate would be increased from 6.1 to 7.6 l/min/m^2 (0.16 to 0.20 gpm/ft^2). After these tests the nozzle angles would be modified and run again. It was unknown whether it would be more effective to: concentrate the AFFF flow near the base of the bulkheads and allow the spreading AFFF film to extinguish the fire; apply the foam to the center area and allow the AFFF film to spread out from there; or, some combination of the two approaches.

Results

<u>Phase I Tests</u>

A summary of the initial Phase I test data is presented in Table 1. The data show that the fixed nozzle system configuration was incapable of controlling the fire (control is defined as 90% extinguishment) at an application rate of 6.1 l/min/m^2 (0.16 gpm/ft^2), regardless of the angle of the nozzles (Tests 1, 4 and 10). Figure 5, taken during Test 1, shows the inability of this application rate to achieve control/ extinguishment. Increasing the application rate 25% (to 7.6 l/min/m^2 (0.20 gpm/ft^2)) resulted in control of the fire (Tests 2 and 3). Control was achieved at the higher application rate

Fig. 5 - Fixed nozzle system at application rate of 6.1 1/min/m^2 (0.16 gpm/ft^2) unable to achieve control/extinguishment

Fig. 6 - Performance of the oscillating monitors (photo taken during Test 9)

TABLE 1

LSD 36 WELL DECK
INITIAL FIRE TEST RESULTS

TEST NO.	DOWNWARD NOZZLE TYPE	DOWNWARD NOZZLE ANGLE	"OUT" NOZZLE TYPE	"OUT" NOZZLE ANGLE	FLOW RATE (gpm)	SYSTEM HEIGHT (ft)	APPLICATION RATE (gal/min/ft^2)	EXTINGUISHMENT TIME(s) 50%	90%	99%	100%
Fixed Nozzle tests											
1	30030	60°	30080X	90°	30	20	0.16	max. 20% extinguishment			
2	30030	30°	30080X	90°	37.5	20	0.20	-	2:00	2:30	-
3	30030	5°	30080X	60°	37.5	20	0.20	-	15 sec	30 sec	40 sec
4	30030	0°	30080X	45°	30	20	0.16	max. 30% extinguishment, cut paths down both sides			
10	30030	5°	30080X	60°	30	10	0.16	50 sec	75% max at 2:00		
8	50gpm	0°	70gpm	45°	50&70	20	0.16	no extinguishment noted			
Monitor tests, 2-250 gpm Feecon monitors, 90° oscillation											
5	monitors at opp. ends - oscillation too fast, pattern too wide							50% max at 1:00 after agent on			
6	monitors at opp. ends - oscillation still too rapid							50% at 30 sec, 75% max at 60 sec			
7	both monitors at same end - one oscillating too slow							25 sec	40 sec	-	3:00
9	both monitors at same end - oscillation correct							-	10 sec	-	15 sec

even with less than optimum nozzle angles. Comparing Test 3 with Test 2 the optimum nozzle angles identified in this test series were one set of downward nozzles 5° from vertical, the other (outward) set 30° from horizontal.

The data also show that the oscillating monitor nozzle concept was very effective, providing control in as little as 10 s and extinguishment in 15 s when both monitors were located at the front end of the simulated well deck (Test 9), as shown in Fig. 6. However, this solution was considered far from ideal considering the severe maintenance problems which would be introduced if monitor nozzles were installed in the well deck.

The initial Phase I tests demonstrated that a flow rate of 114 l/min (30 gal/min) per application point is not sufficient to control this large 279 m^2 (3,000 ft^2) fire. The flow rate had to be increased to 143 l/min (37 gal/min) per application point to control this fire.

PHASE I - POOL FIRE TESTS

Test Layout

The test setup was modified for the Phase I testing as shown in Fig. 4. The test area was lengthened to eliminate, or at least limit, wind effects noted during the initial fire tests. Side feed piping was again used with outlets provided to allow for either a 4.6 or 6.1 m (15 or 20 ft) spacing of nozzles. The longer spacing (compared to 2.3 m (7.5 ft) in the initial tests) was necessary to increase the total flow from each application point while maintaining the 6.1 l/min/m^2 (0.16 gpm/ft^2) application rate.

Tests were conducted with fixed spray nozzles (Bete models 40000 and 40030 which have a larger orifice than the Bete nozzles utilized in the initial tests) and with 304 and 949 l/min (80 and 250 gpm) vari-nozzles. The spray nozzles were utilized in pairs, with one nozzle pointing "down" (0-30 degrees from vertical) and one pointing "out" (30-60 degrees from vertical), shown in Fig. 7. A typical nozzle pair is shown in Fig. 8. Two nozzle pair spacings were utilized: 4.6 m (15 ft) and 6.1 m (20 ft) as shown in Figs. 9 and 10, respectively. This allowed a total flow rate from each pair of 228 and 304 l/min (60 and 80 gpm), respectively. Since the flow characteristics of the spray nozzles were identical, the flow from each individual nozzle was either 114 or 152 l/min (30 or 40 gpm). The nozzle pointing down was a 30° fan nozzle and the nozzle pointing out was a straight

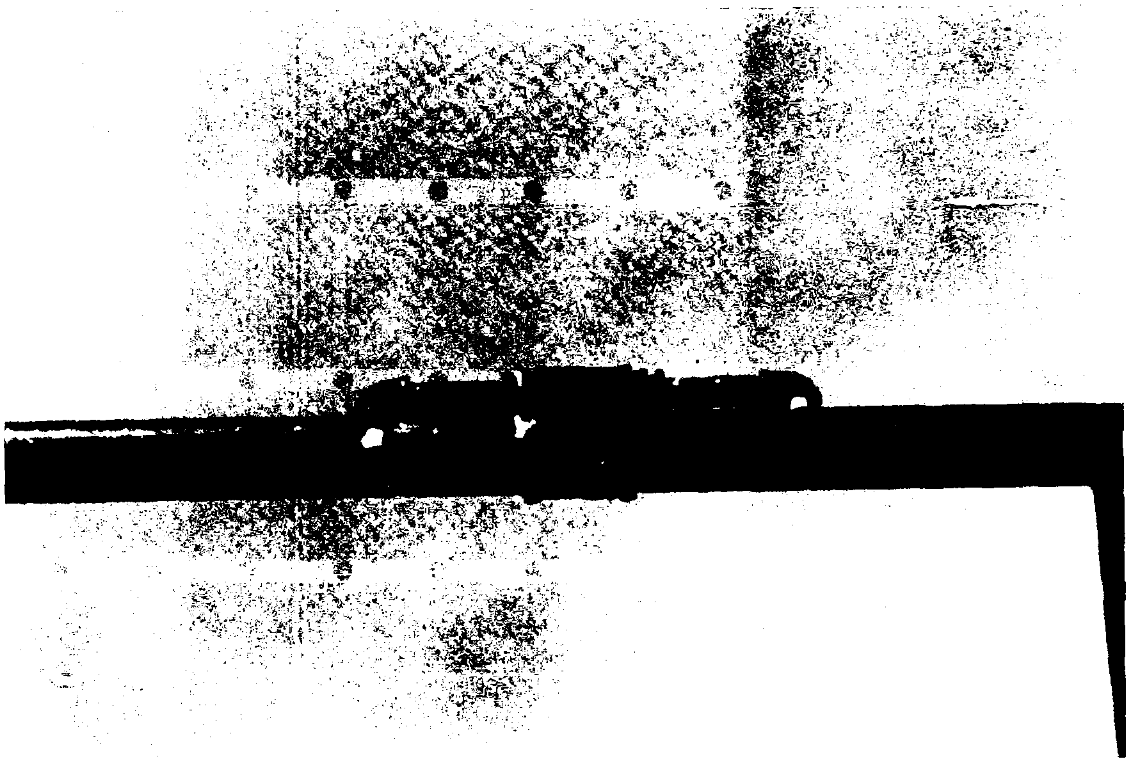

Fig. 7 - Nozzle pair used in Phase II Tests
(Bete models 40000 and 40030)

Fig. 8 - Typical nozzle pair

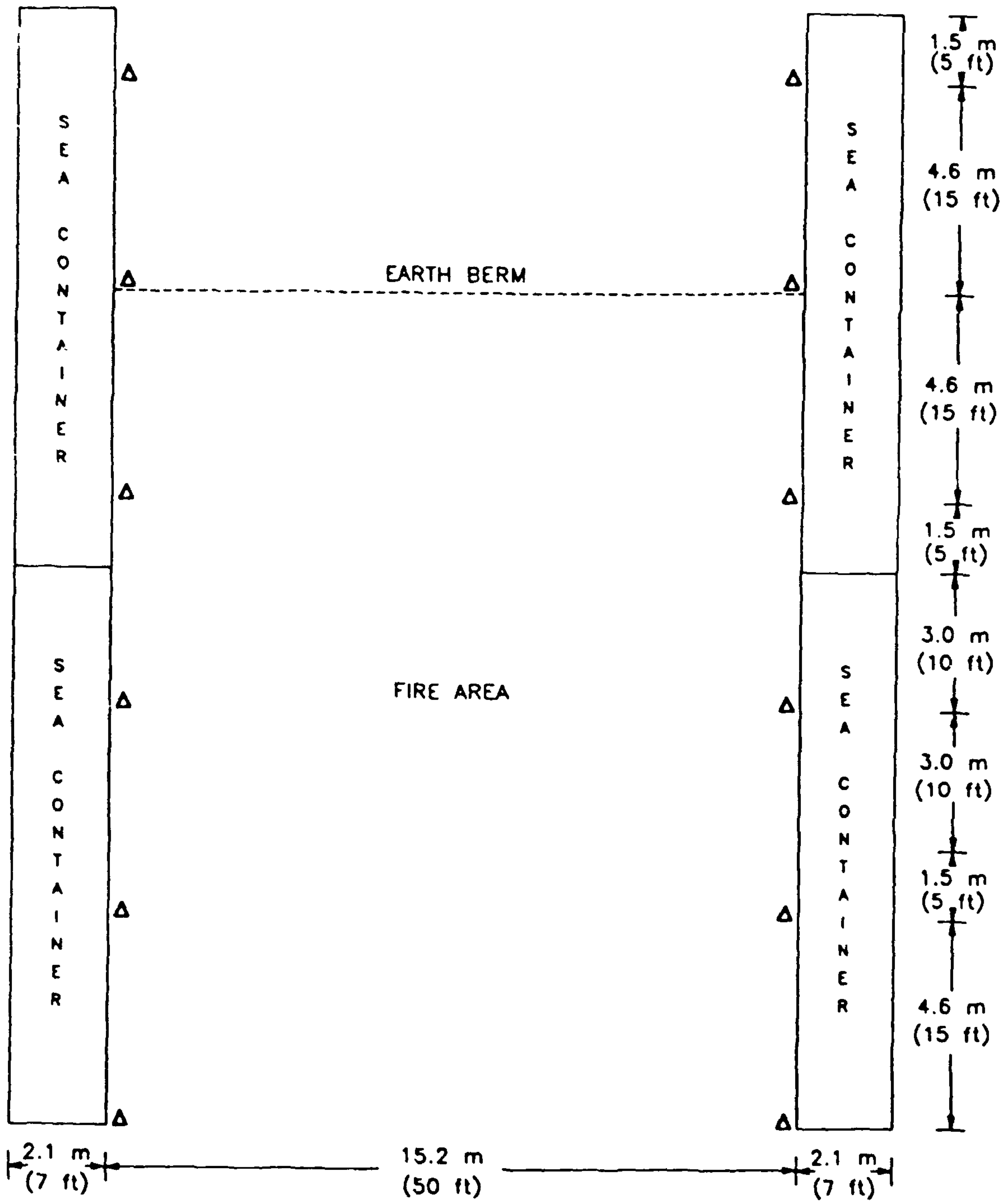

Fig. 9 - 4.6 m (15 ft) fixed nozzle spacing

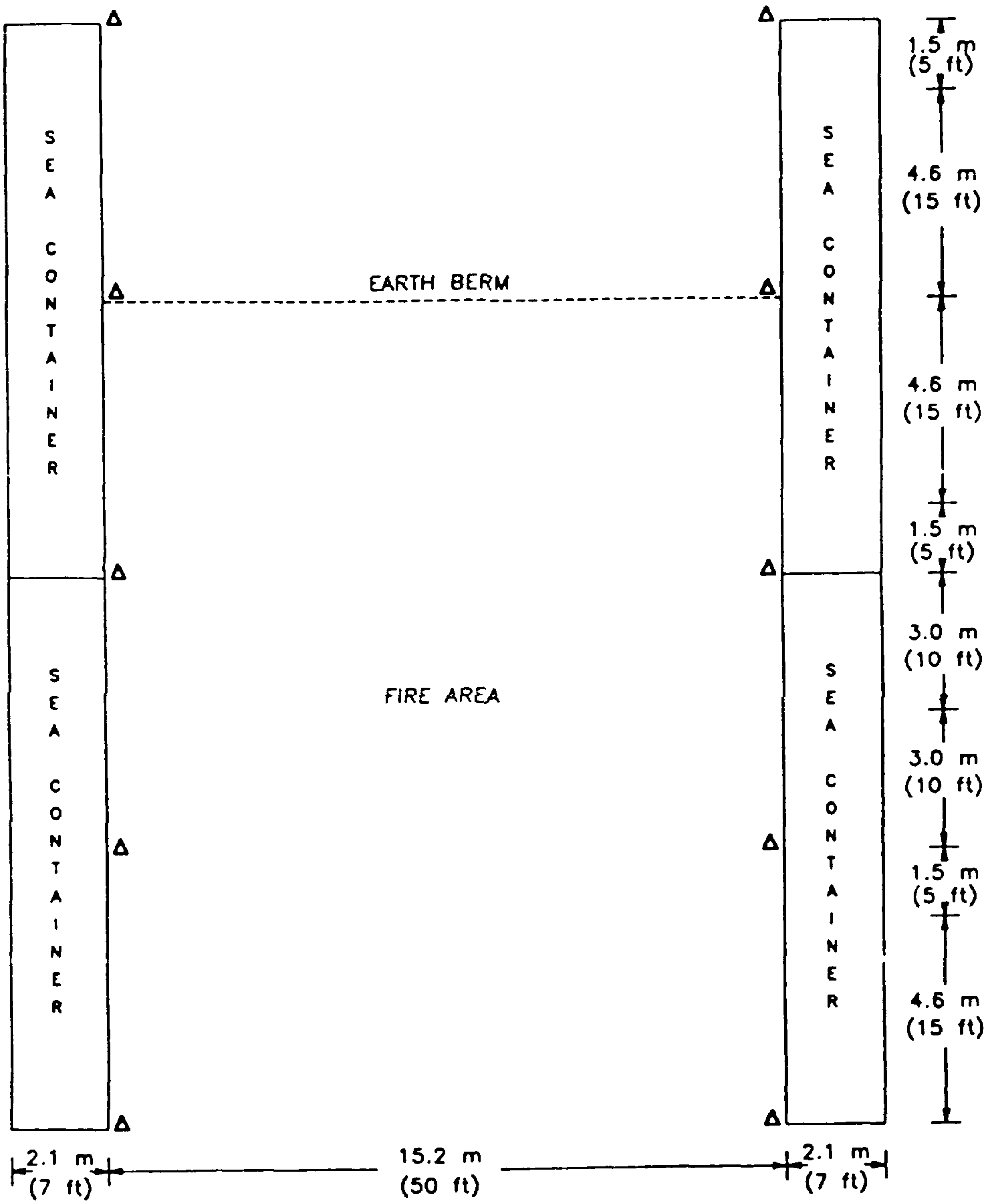

Fig. 10 - 6.1 m (20 ft) fixed nozzle spacing (both spray and vari-nozzles)

stream, although in practice they appeared identical. The 304 l/min (80 gpm) vari-nozzles were spaced 6.1 m (20 ft) apart, as shown in Fig. 10, and were set at an approximate 30° fog pattern. The 250 gpm vari-nozzles were placed 18.3 m (60 ft) apart (with two on one side of the test area and one on the other), as shown in Fig. 11, and were set at a fog pattern of approximately 45°. Tests were conducted with both the 3 m (10 ft) and 6.1 m (20 ft) systems shown in Fig. 4, with the 3 m (10 ft) system simulating a fire in a fully flooded well deck.

Based on the results of this initial test series the following conclusions were drawn and questions raised:

- A flow rate of 114 l/min (30 gal/min) per application point was not sufficient to gain a foothold against this large 279 m^2 (3000 ft^2) fire.

- A flow rate of 143 l/min (37.5 gal/min) per application point was sufficient. What is the minimum flow rate necessary to allow control and/or extinguishment?

- Nozzle angles definitely have a significant impact on system performance. What is the optimum set of angles?

- Could flows at each application point be split between the "down" and "outward" angles, once they were identified?

- What effects would be introduced by the presence of landing craft in the fire area?

A summary of the pool fire test data is presented in Table 2. The data in Table 2 show that the pool fire was controlled (90% extinguished in as little as 30 s, regardless of the system used. Radiant heat levels were also reduced to tolerable levels in approximately 30 s, meaning manual fire fighting teams could begin application of hose streams in that time frame to speed extinguishment. Complete extinguishment was achieved in 45 s.

PHASE II - LANDING CRAFT TESTS

The layout of the landing craft mock-ups is shown in Fig. 12. It was anticipated that the presence of the landing craft in the well deck would add sufficient complexity to the fire scenario that complete extinguishment could not be accomplished by the installed nozzles. Instead, crewmen with hand lines would be required to extinguish the residual fires in and around the landing craft.

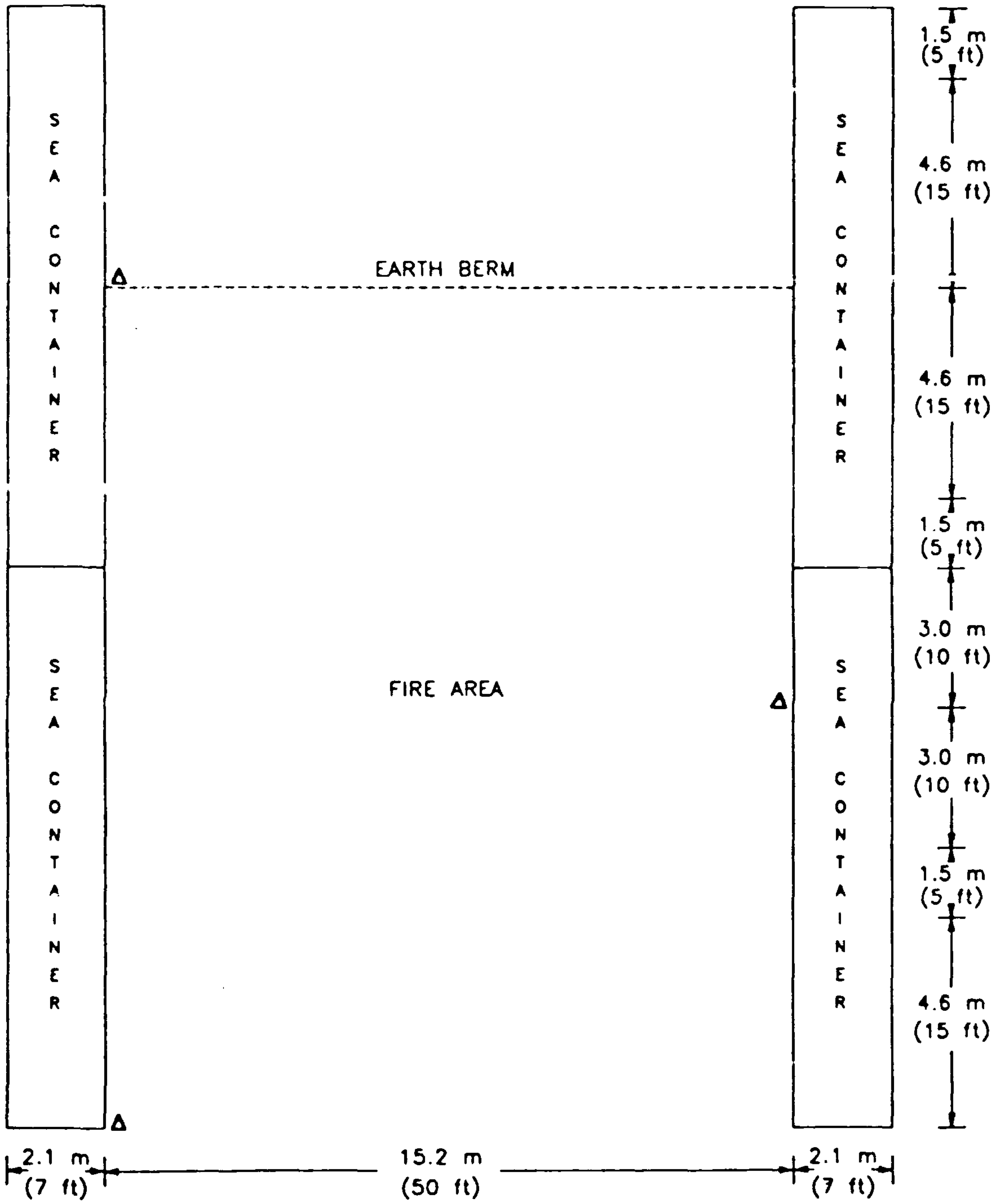

Fig. 11- 949 lpm (250 gpm) vari-nozzle locations

TABLE 2

LSD 36 (MARCH 1987)
SUMMARY OF POOL FIRE TESTS

Test No.	Nozzle Data: Type*	Nozzle Data: Angle*	Nozzle Data: Spacing (ft)	Nozzle Data: Flow Rate (gpm)	Nozzle Data: Height (ft)	Extinguishment Times (s): 50%	Extinguishment Times (s): 90%	Extinguishment Times (s): 99%	Extinguishment Times (s): 100%	Time for Initiation of Manual Firefighting· (s)
11	1-1/2 V.N.	30° fog	20	80	20	20	30	50	--	20
12	1-1/2 V.N.	30° fog	20	80	20	10	20	45	75	13
13	40030&40000	0° & 30°	20	40	20	30	60	--	120	75
14	40030&40000	15° & 45°	20	40	20	15	30	--	90	15
15	40030&40000	30° & 45°	15	30	20	15	30	55	--	30
16	40030&40000	15° & 45°	15	30	20	15	30	50	90	30
17	1-1/2 V.N.	30° fog	20	80	10	15	30	--	45	25
18	1-1/2 V.N.	30° fog	20	80	10	15	30	--	45	25
19	40030&40000	15° & 45°	20	40	10	20	30	60	--	35
20	40030&40000	15° & 45°	15	30	10	15	30	--	65	25
21	2-1/2 V.N.	45° fog	60	250	10	15	30	--	60	30
22	2-1/2 V.N.	45° fog	60	250	10	--	--	--	--	--
23	2-1/2 V.N.	45° fog	60	250	20	40	60	--	--	20
24	2-1/2 V.N.	45° fog	60	250	10	30	60	90	--	80

* Nozzle Type and Angle - V.N. is vari-nozzle, first nozzle type/angle is for fan nozzle, second is for straight stream nozzle (nozzle angles measured from vertical)

\+ Flow Rate - flow rate is nominal flow (gpm) per nozzle, application rate is identical in all cases - 0.16 gpm/ft^2

· Manual F.F. - Flux level low enough ($<10kW/m^2$) to permit initiation of manual fire fighting from catwalk area.

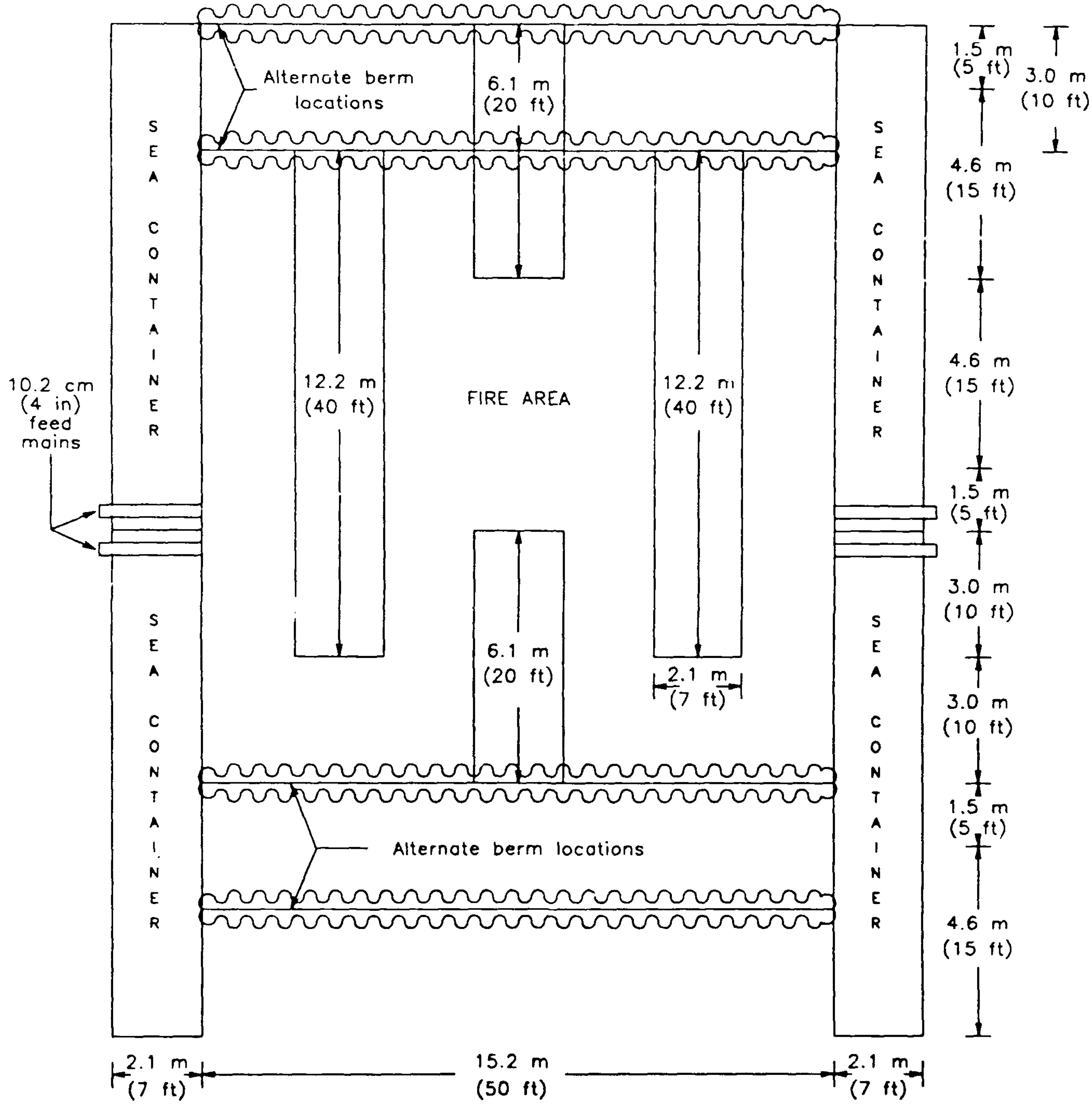

Fig. 12 - Mockup landing craft locations

The data for the fires featuring the simulated landing craft are presented in Table 3. Due to the difficulties experienced in obtaining consistent visual observations of extinguishment efficiency during these tests, radiometer readings (confirmed by adjacent thermocouple readings) were used to define at what point the radiant heat levels were sufficiently reduced to allow crewmen to gain access to the catwalk. (Once crewmen could reach the catwalk, they would be able to direct AFFF hose lines into the well deck and complete extinguishment of the fire.) The data show that the 304 l/min (80 gpm) vari-nozzle was no more effective than the 304 l/min (80 gpm) per pair (6.1 m (20 ft spacing)) fixed nozzles (compare Tests 11 and 12 with 13 and 14). Furthermore, the 949 l/min (250 gpm) vari-nozzle was shown to be less, and sometimes totally, ineffective (Tests 21, 24 and 28). In view of this inability to provide better performance in the presence of the landing craft mock-ups, the vari-nozzles were dropped from consideration since they would be much harder to install and maintain than the spray nozzles. The data also show that the 4.6 m (15 ft) fixed nozzle spacing (with a flow of 228 l/min (60 gpm) per nozzle pair) was not as effective as the 6.1 m (20 ft) spacing (with a flow of 304 l/min (80 gpm) per pair), therefore, the 6.1 m (20 ft) spacing was considered optimum. Since, as stated before, the fixed nozzles would be easier to install and maintain these were considered the optimum choice for the well deck extinguishing system.

ANALYSIS - OPTIMIZATION OF THE NOZZLE ANGLES

Landing Craft Internal Fires

As shown in a comparison of Tests 13, 14 and 15, or Tests 27 and 33, the performance of the paired fixed nozzles could be substantially affected by the nozzle angles used. However, a simple analysis of the potential loading geometries of the well deck shows that no one set of nozzle angles will provide an optimum solution for all loading scenarios. In addition, the tests show that no nozzle configuration will completely extinguish the fire in the well deck nor, in all likelihood, in the landing craft. The objective of the fixed system, therefore, should be a rapid knockdown of the flame volume so that the radiant heat levels will be reduced to the point where hose teams will be able to operate from the catwalks or deck areas. Once these hose teams are able to operate, they should be able to completely extinguish residual fires in the well deck and landing craft in less than a minute.

Fire Along the Well Deck Bulkhead

The tests showed that a potential obstacle to the use of the catwalks or adjacent deck areas by fire team is the fire between the outermost landing craft and the bulkheads. The plume from this fire travels right up the bulkheads and directly impinges on the catwalk or open deck area. A nozzle angle of 30 degrees

TABLE 3

LSD 36 (MARCH 1987)
SUMMARY OF BOAT FIRE TESTS

Test No.	Nozzle Data: Type*	Nozzle Data: Angle*	Nozzle Data: Spacing (ft)	Flow Rate+ (gpm)	Height (ft)	Extinguishment Observations	Extinguishment Time for Manual Firefighting' (s)
25	40030 & 40000	30° & 60°	15	30	10	side channels at 45 s, front & center at 105 s	100
26	1-1/2 V.N.		20	80	10	center out at 30 s, sides at 90 s	110
27	40030 & 40000	30° & 60°	20	40	10	sides at 45 s, center at 90 s	75
28	2-1/2 V.N.		60	250	10	no effect noted	--
29	40030 & 40000	30° & 45°	20	40	20	right side & rear at 60 s, 90% at 120 s	60
30	40030 & 40000	30° & 60°	20	40	20	center at 60 s	50
31	1-1/2 V.N.		20	80	20	sides at 45 s	40
32	40030 & 40000	30° & 45°	20	40	20	center at 60 s, sides at 75 s	150
33	40030 & 40000	15° & 60°	20	40	20	sides at 30 s, center at 60 s, 90% at 1:15	40

* **Nozzles** - V.N. is vari-nozzle, first angle is elevation of fan nozzle from vertical, second angle is elevation of straight stream nozzle (fan nozzle is Bete 400300 and straight stream is Bete 40000)

+ **Flow Rate** - flow rate is nominal flow (gpm) per nozzle, application rate is identical in all cases - 0.16 gpm/ft^2

' Manual F.F. - Flux level low enough (<10 kW/m^2) to permit initiation of manual fire (from vertical) is far too likely to be directed into the outermost landing craft in most loading configurations and was therefore abandoned. A nozzle angle of 0 degrees (straight down) provided less than optimum extinguishment of the pool fires, probably because the foam stream has no velocity component assisting in spread across the deck (away from the bulkheads). A compromise angle of 15 degrees provided this velocity component and still applied foam within a few feet of the bulkhead, thus generally ensuring foam application into the channel between the outermost landing craft and the bulkheads.

Fires in the Center of the Well Deck

Another location which has the potential for harboring a major fire is the center of the well deck. If foam were only applied to the edges of the well deck the intensity of a center fire, combined with the channeling effects of any landing craft (which would physically block foam flow), would severely limit the spread of foam into the central portion of the well deck. This is especially important in that, in less than full loading situations, the landing craft are most likely to be placed near the bulkheads. The tests showed that the "outward" pointing nozzle was equally effective in extinguishing pool fires whether the angle was 30, 45 or 60 degrees (from vertical). The test fires which included landing craft mockups showed little difference in system performance between the 45 or 60 degree angles used. However, a 60 degree angle allows for an overlap in the center of the well deck when operated from the 6.1 m (20 ft) level (above an empty well deck). The 60 degree angle also provides a 75% increase in reach (toward the center) when considering operation from the 3 m (10 ft) level (when the well deck is fully flooded). Therefore, an angle of 60 degrees (from vertical) was considered the best choice. Photographic evidence of the effectiveness of the 15°-60° system is provided in Figs. 13 and 14.

RECOMMENDATIONS

Based on these tests the recommended fixed AFFF system for the LSD 36 class well deck should consist of:

- adequately sized supply piping located along both bulkheads at approximately the 6.1 m (20 ft) level;

- suitable mechanical shielding for the piping and nozzles;

- pairs of deck edge type nozzles [Straight Stream Nozzles (Bete NF40000) and Fan Nozzles (Bete NF40030)] which will flow 152 l/min (40 gpm) at a nozzle pressure of 280 kPa (40 psi);

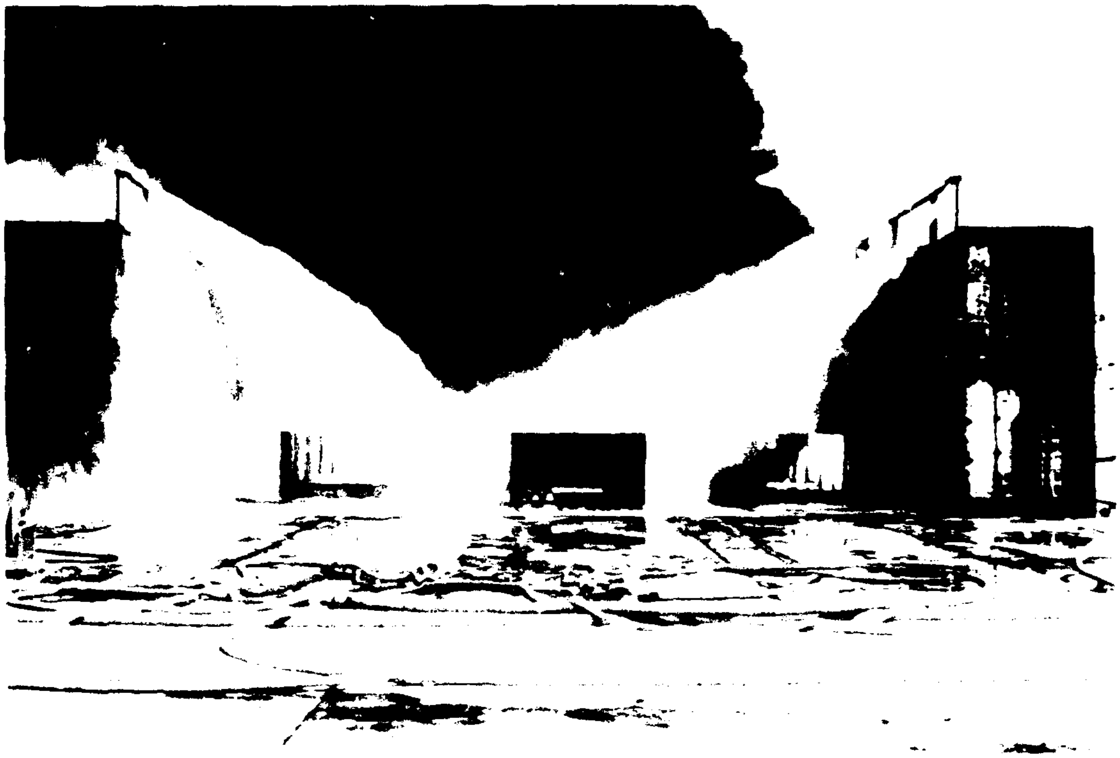

Fig.13 - Results of 15°-60° nozzle system showing fire control at approximately 60 s (Test 33)

Fig. 4 - Results of 15°-60° nozzle system showing 99% extinguishment at approximately 90 s (Test 33)

- nozzle pairs spaced 6.1 (20 ft) apart along the supply pipe; and

- nozzle angles permanently fixed (e.g. by welding) at 15 degrees from vertical for the fan nozzle and 60 degrees from vertical for the straight stream nozzle.

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